CHAPTER VII - TN 38: QUICK ESTIMATES OF PRIMARY BENEFITS

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(and APPENDIX by Do and Beaman)

ABSTRACT

This paper shows that if a travel model where visitor flow equals the product of other variables and $e^{-kD(o,d)}$ WHERE D(o,d) is one way travel distance from origin to destination for main-destination trips of a given purpose the, given certain assumptions, percapita consumer surplus values can be computed very easily. It is essentially computed from the cost per 2-way mile of travel and k. Because k is easily estimated, quick estimates of primary benefits, consumer surplus, are obtained simply by getting the site "demand function" without going through the approach described by Knetsch, Clawson and others to get an aggregate demand function.

Some reasons for using the quick estimation approach endorsed are presented in relation to (1)theoretical justification for the travel model suggested and (2)avoiding arbitrary decisions that must be made using the usual approach to defining Clawson-Knetsch-Hotelling demand function. The matters of (1)including time-bias in the model, (2)the effect of admission fees on identifying time-bias constraints, and some other issues are pursued.

INTRODUCTION

The purpose of this paper is to derive a simple relationship between the primary benefits associated with outdoor recreation and a class of demand relationships which have been used with considerable success in origin-destination recreation studies for Canadian Outdoor Recreation Demand (CORD). This derivation is especially useful because it follows directly from the assumed per mile costs of travel (including time) and the estimated effect of these costs on visitor use of the recreation site.

In what follows, attention is focused on the demand for a single recreation site. Substitute facilities are assumed non-existent and the total level of use of the area is assumed to be less than its economic carrying capacity. (For a definition of the meaning of economic carrying capacity and its relationship to economic carrying capacity, see Fisher & Krutilla 1972.) Since the economic rationale for the travel cost model has been developed in a number of previous studies, (see Smith 1975) the focus of this paper is directed to the derivation of a consumer surplus measure for the total population of users for the recreation site of interest.

DEMAND AND CONSUMER SURPLUS

An individual demand curve is the locus of maximum prices that individual would be willing to pay for each corresponding level of consumption of the good or service involved. Given a single price rationing system, the net benefits to each individual from the provision of the service of interest at a particular price is the sum of the excess willingness to pay at each quantity. This benefit is the area under the income—compensated demand curve less the amount paid for the good or service. These net benefits are generally designated consumer surplus and will be the benefit measure utilized here.

Consider a class of demand functions for a particular recreation site (Equation 1).

(1) $V(j) = \exp(-\lambda\ TC(j))\ f(Z(j))$

WHERE V(j) = the number of trips to the site from origin j during a given time period,
TC(j) = the total per unit (trip) costs associated with engaging in recreation at the site from origin j,
Z(j) = set of additional determinants of demand for origin j,
λ = change in demand with a change in cost per visit $((dV/\Phi\ TC)/V(j))$.

If total unit costs are proportional to distance and the proportionality factor is constant for all origin zones, then Equation 1 can be re—expressed in terms of distance. This transformation is relevant to many CORD studies, since the models have been estimated in terms of distance rather than per unit total costs. Thus assume that total unit costs are given as the sum of travel costs and time costs as in Equation 2.

(2) $TC(j) = (C + t)d(j)$

WHERE C = per mile travel costs,

d(j) = roundtrip distance to the site from origin j, and t = time costs per mile.

Equation 1 can be re-written in terms of distance as follows:

(3) $V(j) = \exp(-\varphi\, d(j))\ f(Z(j))$

WHERE: $\varphi = \lambda(C + t)$.

The total use of a given site with given costs can then be derived by summing Equation 3 over all origins as in Equation 4.

(4) $TU = \Sigma_j \exp(-\varphi\, d(j)) * f(Z(j))$

Consider the effects of a change in unit costs through the introduction of an admission charge, A. The changed total use is given in Equation 5.

(5) $DTU = \Sigma \exp(-\varphi\, d(j) - \lambda A) f(Z(j))$

Since A is constant, by assumption, for all origin zones DTU can be expressed as follows:

(6) $DTU = \exp(-\lambda A)\, \Sigma \exp(-\varphi\, d(j)) f(Z(j)) = \exp(-\lambda A) TU$

If we wish to measure the consumer surplus effects of changes in the admission fees, then we need only integrate Equation 6 over a prespecified region for A as in Equation 7.

(7) $CS = \int TU \exp(-\lambda A) dA = TU(1 - \exp(-\lambda MP))/\lambda$

WHERE the intergral is from 0 to MP (maximum price).

It should be noted that in Equation 7 it is assumed that all other components of price remain unchanged and one considers variations only in the admission charge. Movement from (C+t)d(j) to (C+t)d(j)+MP represents an increase in unit costs and therefore a decrease in use (DTU) and associated loss in consumer surplus (CS).

On a per trip basis (PCS), the consumer surplus for this model is found to be a function solely of the estimated parameter, λ, and the maximum admission charge, MP, as given in

(8) $PCS = \lambda - \exp(-\lambda\, MP)/\lambda$

It is therefore readily computed for any given site. Since many of the CORD models are specified as in Equation 3, direct estimates of λ are not available. Rather one must specify the unit travel and time costs (i.e. C and t). Equation 8 can be re-written in terms of φ as follows:

(9) $PCS = \lambda = \exp(-MP\ \varphi/(t+C))/(\varphi/(t+C))$

IMPLICATIONS

The results of this derivation suggest that for a given class of demand functions it is possible to readily estimate the consumer surplus losses (or gains) associated with increases (or decreases) in the unit costs of a recreation trip that are independent of distance. Moreover, these estimates can readily be derived from estimated equations based on distance and not total unit costs provided the travel and time costs can be assumed to be proportional to distance. Since the models, in which estimates of λ are based, have been reasonably successful in explaining visitor use patterns to Canadian Parks, the simple computational formula provided should offer a benchmark for ready calculation of the potential benefits associated reductions to user fees.

It is nonetheless true that this derivation requires a number of simplifying assumptions. Among the most important of these are the absence of substitute facilities and of on-site congestion. In addition, the measure of consumer surplus are only relevant for the same dollar change in the unit costs of users at all origin zones. If the price structure changes differentially to consumers at different origin zones, then the analysis is of limited relevance.

APPENDIX: Logical/Technical Issues

By N. Hung Do and J. Beaman

In the preceding paper a number of matters have not been carried to their "logical" end because of objects that can be raised while other considerations were not pursued because their pursuit would constitute a deviation from the main theme of the paper. Rather, it was decided to have an appendix to the paper where in a point by point way the lines of consideration that were only raised in the paper are pursued to some extent.

OBTAINING ACTUAL PER CAPITA CONSUMER SURPLUS VALUES

In the paper, formulae were developed that depend on some "highest price that would be paid". Defining such a price is important if one is using distance functions such as the inverse of distance to some power for which integrals may not converge. But for the exponential function, if MP, the maximum price, is reasonably large so that most of the area under the demand curve occurs "before" MP, then one might as welt consider the results obtained by letting MP approach infinity.

If one simply lets MP approach infinity then one obtains consumer surplus, CS, as:

(A1) $CS = \int TU \exp(-\lambda A)\, dA = TU/\lambda$

WHERE the integral is from 0 to "infinity".

To obtain this on a per visit basis (PCS), one divides by TU, thus the consumer surplus is given by:

(A2) $PCS = 1/\lambda$

The per capita consumer surplus for the model depends solely on the estimated parameters λ which in reality can be interpreted as:

(A3) λ = "resistance of distance"/cost per mile of travel

The interpretation given above is based on the fact that when one goes from a price formulation to the distance formulation which is usually used in carrying out regressions, one has:

(A4) $\exp(\lambda A) = \exp(-\zeta A/C)$

WHERE in terms of TN 14, 1 is the impedance of distance and where C is cost per two-way mite (further described on Table 1). So, as described by Beaman and Lehtiniemi (1975) if one has 1 values such as those given in TABLE 1, one can get quick estimates of per capita consumer surplus such as those shown by using:

(A5) $PCS = 1/\lambda = C/\zeta$

ARC ELASTICITY CONSIDERATIONS

One may note that with the type of demand function defined earlier, the arc elasticity of demand with respect to admission fees is less than one, or in other words reflects inelasticity. Since the arc elasticity is defined as:

$$\varepsilon = \frac{\text{Variation of demand * Average of price}}{\text{Variation of price * Average of demand}}$$ one obtains for the model

$= (\exp(-\lambda A)-1)/(\exp(-\lambda A + 1)$

which is less than zero and greater than -1 but approaches -1 as A becomes large.

As such $|\varepsilon| < 1$ means that the demand is inelastic with respect to admission fees regardless of the value of A. This result could be considered consistent with the findings of McConnell and Duff (1976). They report that the demand function is more elastic with respect to travel costs that it is with respect to admission charges. However, the problem is what is the elasticity with respect to travel costs? If one says that the A considered previously is travel costs rather than admission charges and then use the same demand function or introduced an AT component for:

$DTU = \exp(-\lambda(A + AT))TU$

then obviously travel and admission cost elasticities are the same when comparable charges in A and AT are considered. Only if time bias is explicitly considered (as is done subsequently) does one obtain results on which the statement of McConell and Duff can be checked.

TABLE 1: CONSUMER SURPLUS VALUES IN DOLLAR PER PARTY TRIP FOR DIFFERENT TYPES OF VISITS TO CANADIAN PARKS*

Consumer Surplus in $ per Party Trip	Type of Trip	Impedance of Distance (1) Source
3.49	Main Destination Camping Trip to Camp in a Publicly Provided campsite**	.00709 Wang***
3.97	Main Destination Day-Use	.0706 TN 7
4.83	Trip for Weekend	.058 TN 35
6.36	Holiday trips**	.044 TN 35
5.60		.050 TN 35
9.33	Enroute Stop-Over Camping Visit	.03 TN 18

*All computations are based on "the average party" having the belief that all relevant trip costs are such that each mile of travel costs 14 cents. Thus, c, the cost per 2-way mile (each mile must be covered coming and going), is 28 cents.

** These figures should be taken to apply to weekend and holiday trips because, even though the studies did not separate out trips after work, the number of these is so small compared to other trips that they should only cause a slight low bias in the figures presented.

*** The report is "A prediction Model for Camping Visitation", by Darsan Wang. Report 158 of Department of Tourism Recreation and Cultural Affairs, Province of Manitoba.

POINT ELASTICITY AND THE MARGINAL EFFECT OF A CHANGE IN PRICE ON DEMAND

Point elasticity for the demand function defined by Equation 6 is:

$$(d(DTU)/dA)/(A/DTU) = -\lambda A \exp(-\lambda A)\, TU/DTU = -\lambda A\, (DTU/DTU)$$
$$= -\lambda A$$

However, it is considered that this negative elasticity, which goes to infinity as price is increased, is deceptive. The reason is that one should consider the following:

MC = the limit of proportional change in DTU/change in price = $-\lambda$.

The fact that MC is equal to a constant means that charging a dime more causes the same proportional change in DTU whether A has been doubled from 10 to 20 cents or increased from $100.00 to $100.10. This tatter way of expressing how demand is changing with price is crystal clear in terms of what is meant: a certain percentage change in demand is associated with a particular change in price. What is really important to note is that because MC does not change with A, behaviourally it can be considered to reflect a person's belief that (say) 10 cents is just as important if one spends $1.00 on a certain type of trip as if one spends $500 on that kind of trip. Intuitively one may feel that if one was willing to spend $500, ten cents would not mean as much as it does when it amounts to a 10% increase in trip costs. So there may be good behavioural grounds on which to object to the demand function based on the $\exp(-\lambda D)$ distance function.

How MC varies for other distance functions can be inferred from Figure 2 of TN 14. This is because the definition of MC here is basically equivalent to the definition of "impedance of distance", IDF(d), in TN 14.

For example the traditional distance part of a gravity function, d^{**a}, has an impedance function (1 - a)/D which in terms of cost would imply that for people who travel further than D an added cost, such as an admission cost A, would be introduced into the denominator of the impedance function as follows:

$MC = (1 - \alpha)/(D + A/C)$ a > 1

or in cost terms where Al = CD:

$MC = C(1 - \alpha)/(A1 + A)$ for a > 1

For this function ten cents does have less effect on behaviour when total trip expenditures are large rather than small.

From a practical perspective three points which are not introduced in more detail later show the lack of immediate importance of the issues just raised. Firstly, over the range of distance in which "trip types" can be considered constant all distance functions are fairly similar in shape and can even be considered to have "relatively constant" average impedance of distance. One can see the similarity of distance function in Figure 1 of TN 14. The problem just cited is a collinearity problem and relates to a second concern. Because of collinearity problems it is not likely that a structurally adequate trip distribution model can be identified using the data usually employed to calculate such models. Getting a correct consumer surplus depends on getting a correct model, particularly when dealing with non-isolated sites. Clearly in the context of TN 11, even if a correct per capita consumer surplus can be computed, there is a need to assess (1) to which sites it will be distributed and (2) how total visits made in a system will be influenced by the "supply generates demand" effect. The third problem is that the formulation presented is for isolated sites. To the knowledge of these authors only Knetsch and Cheung have used a systems model (albeit a rather naive one) to get a demand function for a proposed non-isolated site.

TIME BIAS

It can be noted that the demand function defined in Equation 3 has a term which relates to value of time. This is because of the problem of time bias (see Reference 9). However actually estimating time bias effects raises some interesting estimation problems. For example, the Cesario model (see TN 4) can be written as follows with hard time considered:

(A6) $V(o,d) = A(d)E(o) \exp(-\lambda(D(o,d) + kt(o,d) + C(d)/c)$ WHERE $t(o,d)$ = travel time,
$C(d)$ = admission charge, and
c = per two-way mile travel costs.

But, since using an average velocity figure, v, t(o,d) can be rewritten as:

(A7) $kt(o,d) = k(1)D(o,d)$ WHERE $k(1) = kv$.

Now by taking logs of both sides of the equation, as one would to carry out a regression, one gets:

(A8) $\text{Ln } V(o,d) = \ln A(d) + \ln E(o) - (\lambda + \lambda\, k(1))\, D(o,d) - \lambda\, C(d)/c$

But because both ln A(d) and $\lambda C(d)/c$ are destination effects, they can and must be combined:

(A9) $\ln V(0, d) = a'(d) + \ln E(o) - (\lambda + \lambda\, k(1))\, D(o,d)$ WHERE $a'(d) = \text{In } A(d) = I\, C(d)/c$.

The parameters of an equation written in this form can usually be estimated. However, as noted, k(1) cannot be determined separately from so money and time costs are not separable because of collinearity. This is because, if parameters are to be estimated, there cannot be a linear relation between time bias and attractiveness that allows one to be explained by the other (the design matrix must be of full rank, see Reference 50). However from Equation A6 to A9 one sees that as long as travel time is roughly proportional to D(o,d) and C(d) reflects costs rather than C(o,d), the terms in Equation A6 can be grouped as in Equation A9 and thus the critical time bias parameter k(1) cannot be identified. Thus there appears to be little likehood of an empirical derivation of the time bias constant! In fact, in experiments carried out using a model based on Ontario but in which t(o,d) was considered to be a non-linear function of D(o,d) (D(o,d) to powers of 1/2 to 3 were used.) So, it was still found money costs and time costs were too highly correlated to allow one to get good estimates of k(1).

At least one gets Equation A9, unless a person has data on visitor use of one or more destinations for different admission fees (or if some parks charge different rates for people from different origins). Time bias (k) cannot be identified using Equation A6.

ELASTICITY WITH TIME BIAS

Earlier discussion cited a view by Duff and McConnel on elasticity. However, it was indicated that their statement lacked meaning until time bias was introduced into the demand function formulation. So now consider that the expression derived earlier means that the arc elasticities which are relevant are:

$EA = |(\exp(-\lambda\ k(1)A) - 1)/(\exp(-\lambda\ k(1)k)\ 1)|$

$ET = |(\exp(-\lambda\ A) - 1)/(\exp(-\lambda\ A)\ 1)|$

WHERE EA = admission charge elasticity; ET = combined time - distance cost elasticity. Solving for the intersection of these two functions (EA = ET) one sees that for k(1) not equal to one they only intersect at zero and infinity. From the derivatives of the functions, one learns that slope of EA is less than of ET and both slopes do not change sign but go to zero as A becomes large. So it follow that as soon as A is non-zero:

$$EA < ET$$

In economic terms the preceding means that the demand function is more inelastic with respect to admission fee than it is with respect to total travel costs. So this result is not fundamentally inconsistent with that found by McConnell and Duff. They simply stated that a decrease in demand due to the increase in travel costs is stronger than it is with the increase in the admission prices. However, one wonders if they were referring to short-term reactions to price changes rather than to the equilibrium demand elasticities computed here.